Vision and Voyages

For Planetary Science in the Decade 2013-2022

Steve Squyres
Cornell University
Chairman, Planetary Science Decadal Survey

The 2013-2022 Decadal Survey: Implications for Mars

Philip Christensen
MEPAG June 16, 2011

What Is A Decadal Survey?

- Once every ten years, at the request of NASA and NSF, the National Research Council carries out a “decadal survey” for planetary science.
- The decadal survey involves broad participation from the planetary science community.
- It is the primary scientific input that NASA and NSF use to design their programs of planetary science and exploration.

- This decadal survey applies to the decade from 2013 to 2022.

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Laurence Soderblom, *Vice Chair*
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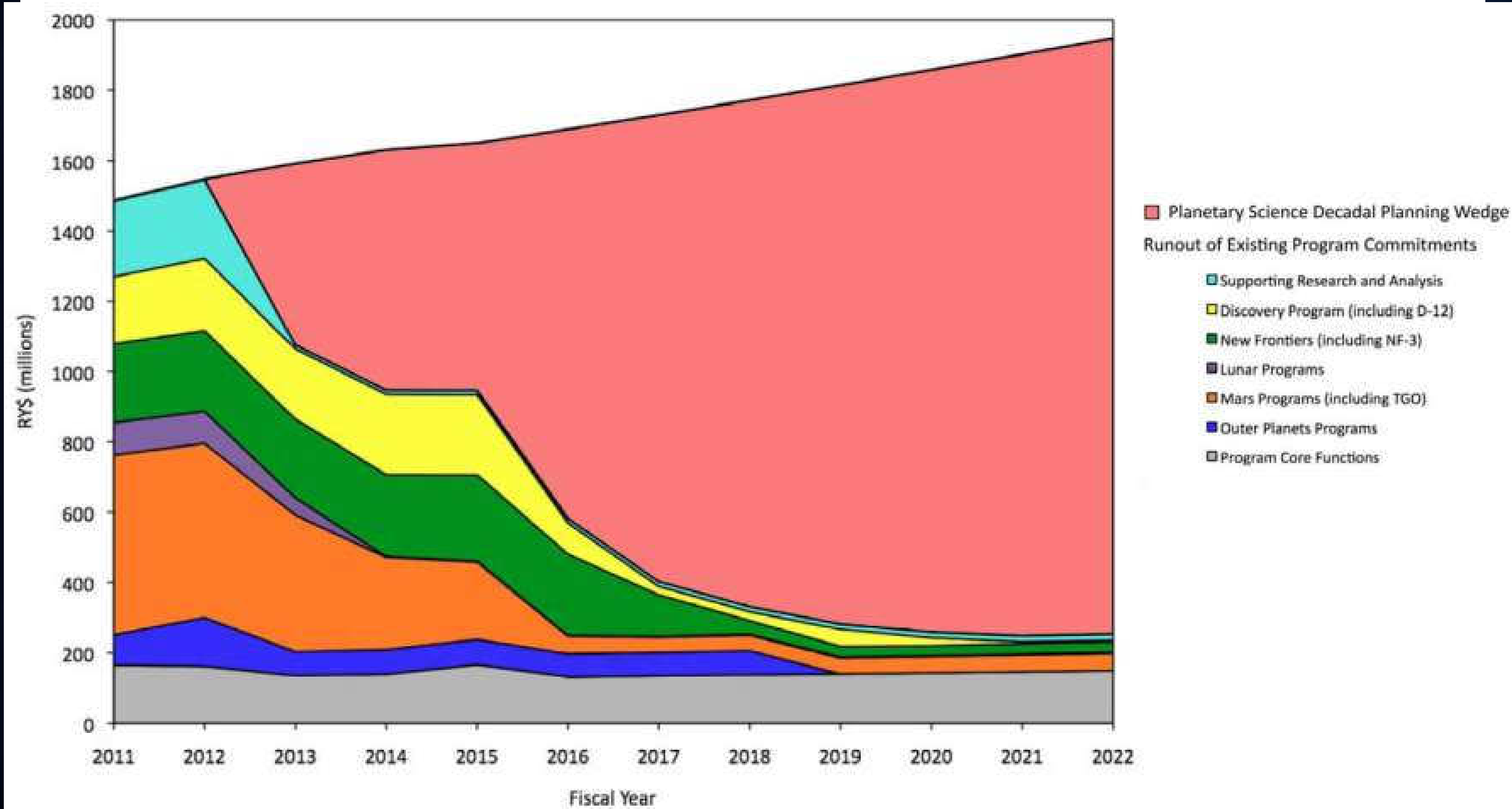
Key Guiding Principles

- Governed by ‘Statement of Task’ provided by NASA and NSF
  - All recommendations should be science driven
  - Plan should fit within the projected budget
- Mission cost a critical element of prioritization
  - All recommended missions must go through rigorous, independent cost evaluation
- Develop plan that has resilience to budget changes
- Mars science priorities integrated into overall solar system science priorities
  - Previous Decadal Survey considered Mars separately
- Continued existence of Mars Program not guaranteed

It All Has To Fit

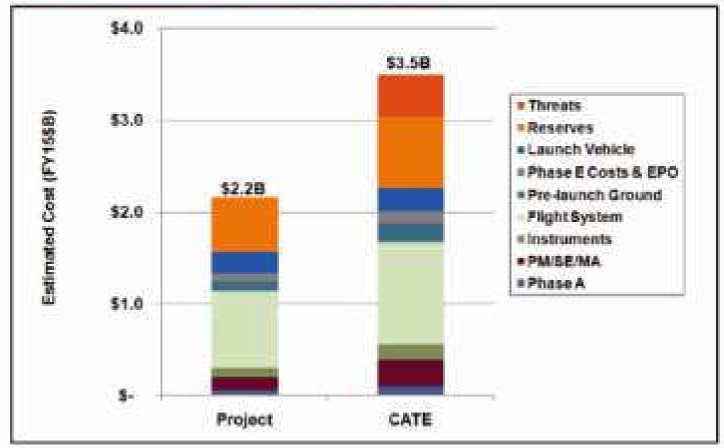


(Data and projections provided by NASA)

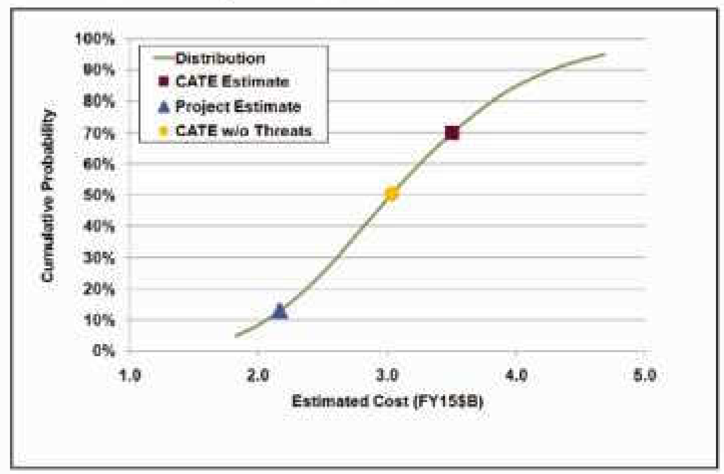
Cost and Technical Evaluations

- After studies were completed, high-priority mission candidates were subjected to a detailed Cost and Technical Evaluation (CATE) by Aerospace Corporation.
- CATE estimates are based on multiple methodologies, including <u>actual costs</u> of analogous past missions, to avoid the optimism inherent in other cost estimation processes.
- <u>The result is some sticker shock</u>! But realism is essential.
- All costs are in $FY'15.

Key Cost Element Comparison



Cost Risk Analysis S-Curve



Mars Panel Members

- 13 Members
  - Represented science from core to atmosphere
- Philip Christensen (Arizona State University) Chair
- Wendy Calvin (University of Nevada, Reno) Vice-Chair
- Raymond Arvidson (Washington University in Saint Louis)
- Robert Braun (Georgia Tech); *Term ended Feb. 1, 2010*
- Glenn Cunningham (Consultant)
- David Des Marais (NASA – Ames Research Center)
- Linda Elkins-Tanton (Massachusetts Institute of Technology)
- François Forget (Université Paris)
- John Grotzinger (California Institute of Technology)
- Penelope King (University of New Mexico)
- Philippe Lognonné (Institut de Physique du Globe de Paris)
- Paul Mahaffy (NASA – Goddard Space Flight Center)
- Lisa Pratt (Indiana University)

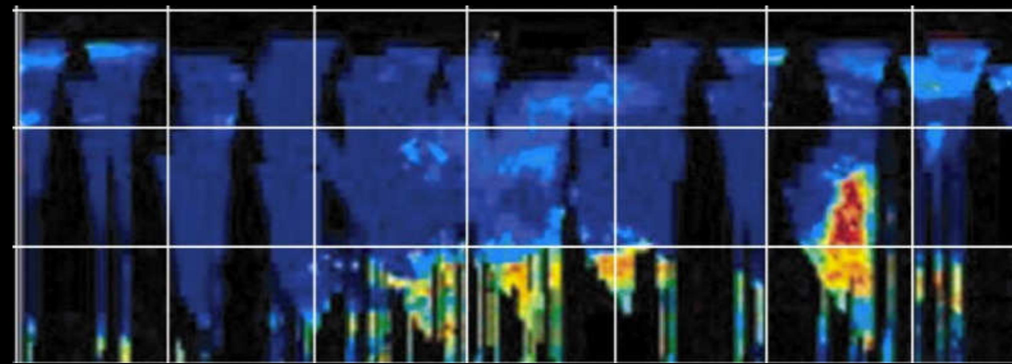
Mars Panel Process

- Carefully considered inputs from Mars science community in form of past NRC reports and recommendations, MEPAG reports and documents, and submitted ‘white papers’
- Considered in detail:
    - MER-class rovers
    - Mars geophysical network
    - Mars polar climate mission
    - Trace Gas Orbiter
    - Mars *in situ* science versus sample return
    - Mars sample return campaign
        - Mars Astrobiology Explorer-Cacher rover
        - Mars Sample Return Lander
        - Mars Sample Return Orbiter

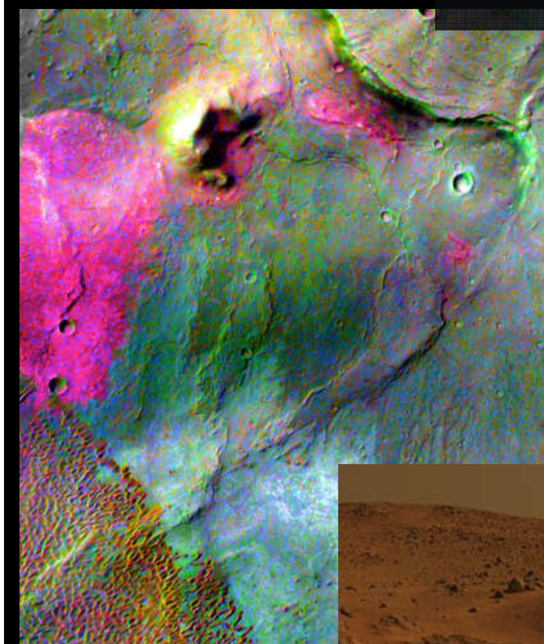
Mars Panel Outcome

- MER-class rover
  - Evaluated by Steering Committee as ‘flagship-class mission’ and given low priority relative to other solar system science objectives
- Network mission
  - No room in budget if sample return goes forward successfully
  - Not approved by Steering Committee for CATE study
  - Geophysics lander included as potential Discovery mission
    - Recent selection of Bruce Banerdt’s GEMS Discovery mission
- ESA/NASA Trace Gas Orbiter strongly endorsed

- Concluded that “*analysis of carefully selected and well documented samples returned from a well characterized site will provide the highest scientific return on investment*”



The Mars Panel Report and Recommendations



Philip Christensen
Wendy Calvin for
the Mars Panel
July 13, 2010

Mars Report Overview

- Mars Report focused on five major topics:
  - Role Mars plays in solar system science
  - Mars science goals with objectives and investigations
  - Success of the Mars program and recent science results
  - Rationale for Mars sample return, with the science objectives of understanding early solar system processes and potentially habitable environments, and pursuing questions related to life
  - Prioritized mission suite, beginning with the Trace Gas Orbiter, with the emphasis for the decade on a sample collection rover and the technology development for sample return

Sample Return Priority Has Emerged

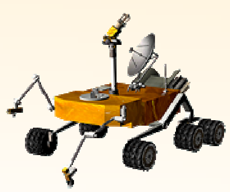
- Previous NRC studies have placed high priority on the science that can be accomplished by the analysis of samples returned from Mars
- In addition to *in situ* analyses, it is now recognized that addressing astrobiological questions also requires intensive and iterative analyses that can only be done on Earth
- Exploration of Mars over the last 15 years has followed the logical flow laid out in the 1995 and 2007 Mars Exo-/Astrobiology Strategy:
    - Identify sites of interest from orbit
    - Explore role of water on the ground
    - Investigate habitability
- Highest priority science goal is to address in detail the questions of habitability and the potential origin and evolution of life on Mars
- ***There is consensus in Mars community that return of a carefully selected suite of samples from a diverse, well-characterized site will make the greatest progress at this point in Mars exploration***

Prioritized Mars Missions for Next Decade

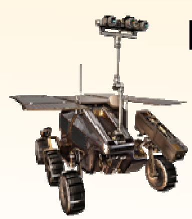
- Begin the sample return campaign
  - First element is MAX-C rover
    - 350 kg, MER-like, solar powered, medium traverse rover
    - Focused on collecting high-quality sample return cache
    - Modest suite of high-heritage, low-risk instruments
    - Include ESA ExoMars rover
  - *Note that 2018 is an excellent surface opportunity*
- Fly the Trace Gas Orbiter
- Develop the key technologies for sample return
  - Mars Ascent Vehicle; on-orbit rendezvous and capture; planetary protection
- Move toward completion of sample return
- Include geophysical/atmospheric surface missions/networks in New Frontiers and Discovery programs

Sample Return Campaign Rationale

- Three-element campaign separates sample return into achievable pieces that each contain a limited set of technical challenges
  1. Sample caching rover: Sample collection and isolation
  2. MSR Lander: Mars ascent vehicle
  3. MSR Orbiter: On-orbit rendezvous and capture; back planetary protection
- Architecture provides resilience against failures
  - Collection of 2 caches by MAX-C allows for subsequent failure of MAV or orbiter without having to refly MAX-C
- Modular approach allows sample return to begin and to proceed at a pace determined by prioritization within the solar system objectives and by available funding



MAX-C



ExoMars (ESA)

Why sample return, and not in situ?

There are three primary reasons why MSR is of such high value compared to in situ alternatives.

1. Measurement diversity. Investigations are not hypothesis-constrained. Essential follow-up.

2. Complex sample preparation, including sample-related decision-making

3. State-of-the-art instruments are large/complex

Image courtesy Dimitri Papanastassiou

2018 Mission

- Mars Panel recommended 2018 mission using skycrane derivative to land MAX-C and Exo-Mars rovers
- All discussions with Steering Committee made it clear that this mission is the beginning of a 3-element sample return campaign
    - Eventual Steering Committee prioritization was based on this assumption
- Aerospace Corp. evaluated cost of MAX-C/Exo-Mars mission at $3.5 B
    - High cost due primarily to necessary changes in skycrane
- This concept was rejected by Steering Committee
- Mars Panel requested study of a descoped option in which skycrane was 'build to print'
    - Cost of descoped option was $2.5 B
- Exo-Mars element was not precluded in the descoped option
- Implementation of international partnership left to NASA and ESA

Flagship Missions
(in priority order)

1. Begin NASA/ESA Mars Sample Return campaign: *Descoped Mars Astrobiology Explorer-Cacher (MAX-C)*

2. Detailed investigation of a probable ocean in the outer solar system: *Descoped Jupiter Europa Orbiter (JEO)*

3. First in-depth exploration of an Ice Giant planet: *Uranus Orbiter and Probe*

4. Either *Enceladus Orbiter* or *Venus Climate Mission* (no relative priorities assigned)

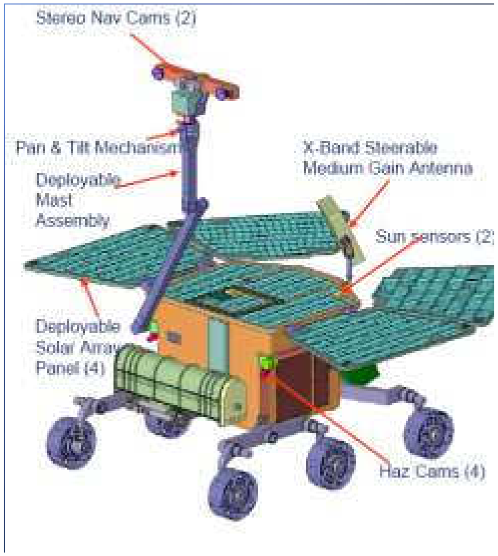
The Need For A Descope

- The CATE estimate for the cost to NASA of MAX-C/ ExoMars is $3.5 billion. This is too large a fraction of the planetary budget.

- *Fly MAX-C only if it can be conducted at a cost to NASA of ≤ $2.5 billion FY'15.*

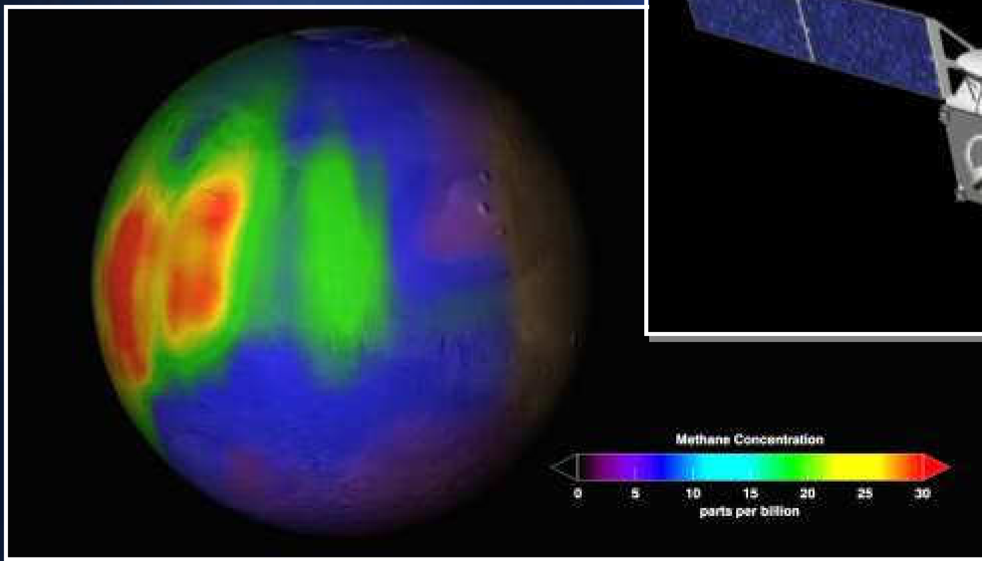
- Descopes must be equitable between NASA and ESA. *It is critical that the partnership with ESA be preserved.*

- If the goal of $2.5 billion cannot be achieved, MAX-C should be deferred to a subsequent decade or cancelled.



- No alternate plan for Mars exploration is recommended. If MAX-C cannot be carried out for a cost to NASA of ≤ $2.5 billion then other Flagship missions take precedence.

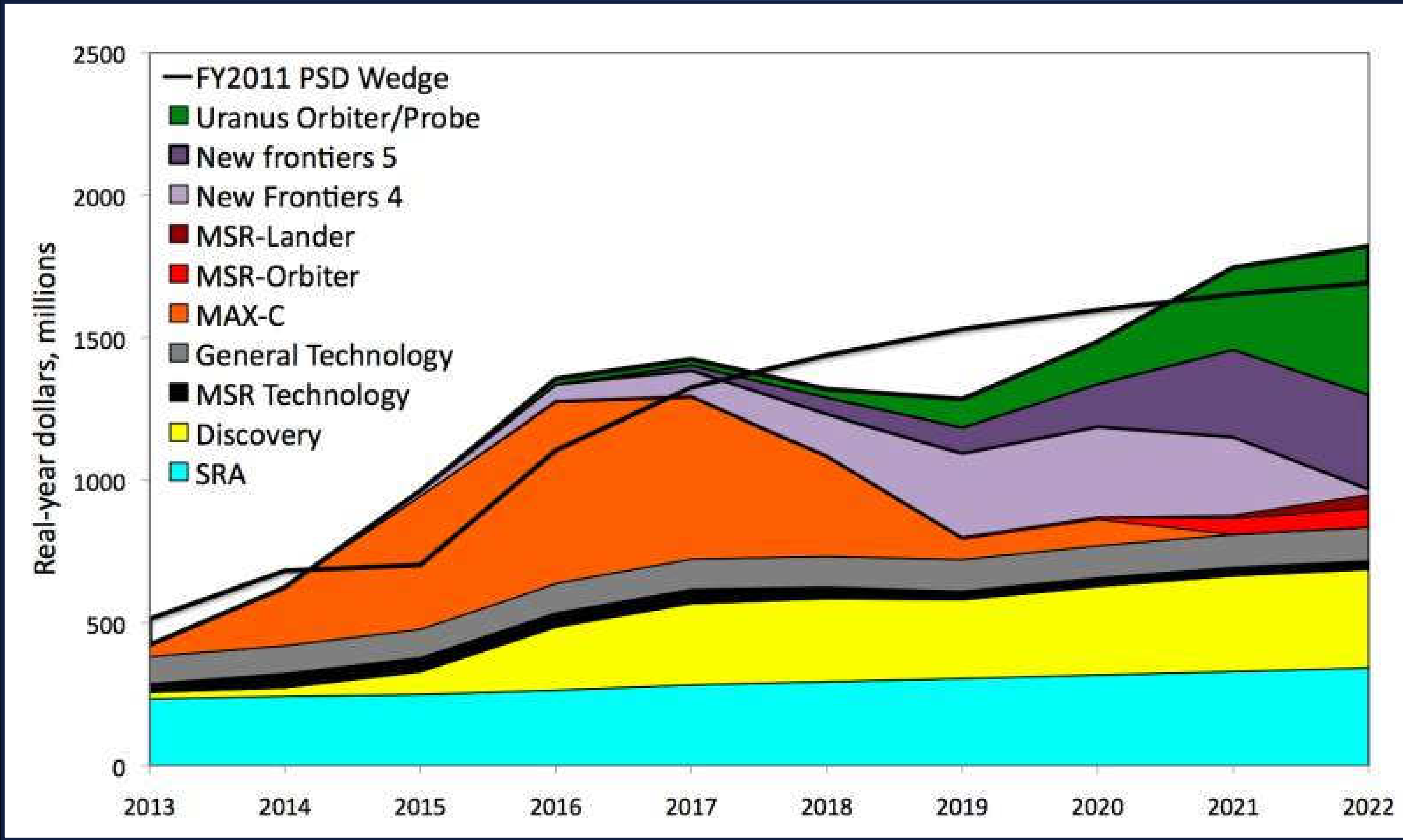
Mars Trace Gas Orbiter



- Joint mission with ESA: NASA provides most of the science payload, and the launch.

- *Carry out this mission as long as this division of responsibilities with ESA is preserved.*

The Cost-Constrained Program



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OF THE NATIONAL ACADEMIES

Summary

- Mars Program came out of the Decadal Survey process in excellent shape
- Initiation of a sustained Mars sample return campaign strongly endorsed by NRC
- The first step in sample return - the 2018 sample collection rover – ranked as the highest priority U.S. flagship mission
- International partnership strongly endorsed
- Decadal Survey, appropriately, left the details of program implementation to NASA and ESA leadership

[redacted]

Role of Mars in Planetary Science

- Many of the key questions in solar system science can be addressed effectively at Mars:
  - Solar system history
  - Planetary evolution
  - Potential for life
- Mars provides the opportunity to pursue origin and evolution of life questions
  - Clear potential for past and possibly present biological activity
- Mars has a well-preserved record of its climate and geologic evolution exposed at the surface
  - A comparable record of ancient planetary processes, including those possibly leading to the origin of life, exists on no other terrestrial planet, including Earth
- Mars is the most accessible place in the solar system where these highest-priority science questions can be addressed
- A well-executed program has brought us to where the next major step in exploration can be taken

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Guiding Principles

- Science Comes First: All recommendations must be first and foremost science-driven.

- Community Involvement: Solicit community input throughout the process.

- Transparency and Openness: Make the process as open and visible to all interested members of the community as possible.

Statement of Task

- The decadal survey was governed by a “Statement of Task”.
- The Statement of Task was provided by NASA and NSF, with input from OMB.
- The Statement of Task emphasized that all recommendations should be science-driven.
- It also placed a strong emphasis on recommending a plan that can be carried out in full using funding projected to be available.

Overarching Mars Science Questions

- What are the nature, ages, and origin of the diverse suite of geologic units and aqueous environments evident from orbital and landed data?
- How, when, and why did environments vary through Mars history and did any of them host life or its precursors?
- What are the inventory and dynamics of carbon compounds and trace gases in the atmosphere and surface, and what are the processes that govern their origin, evolution, and fate?
- What is the present climate and how has it evolved on time scales of 10 Ma, 100 Ma, and 1 Ga?
- What are the internal structure and dynamics and how have these evolved over time?

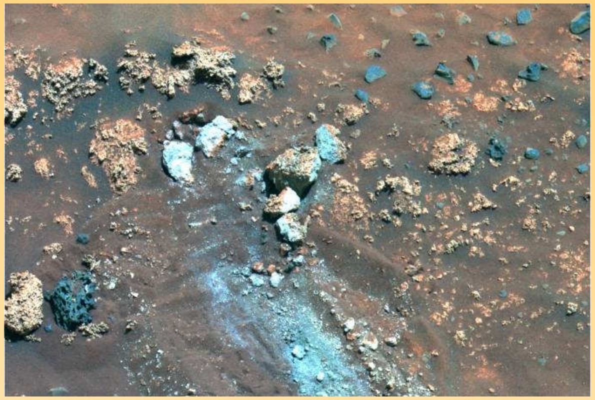
Mars Science Goals and Objectives

- Life: Determine if life is or was present on Mars
  1. Assess the past and present habitability of Mars
  2. Characterize carbon cycling in its geochemical context
  3. Assess whether life is or was present on Mars

- Climate: How the climate of Mars has evolved over time to reach its current state, and what processes have operated to produce this evolution
  1. Characterize Mars' atmosphere, present climate, and climate processes
  2. Characterize Mars' recent climate history and processes under different orbital configurations
  3. Characterize Mars' ancient climate and climate processes

Sample Requirements Well Defined

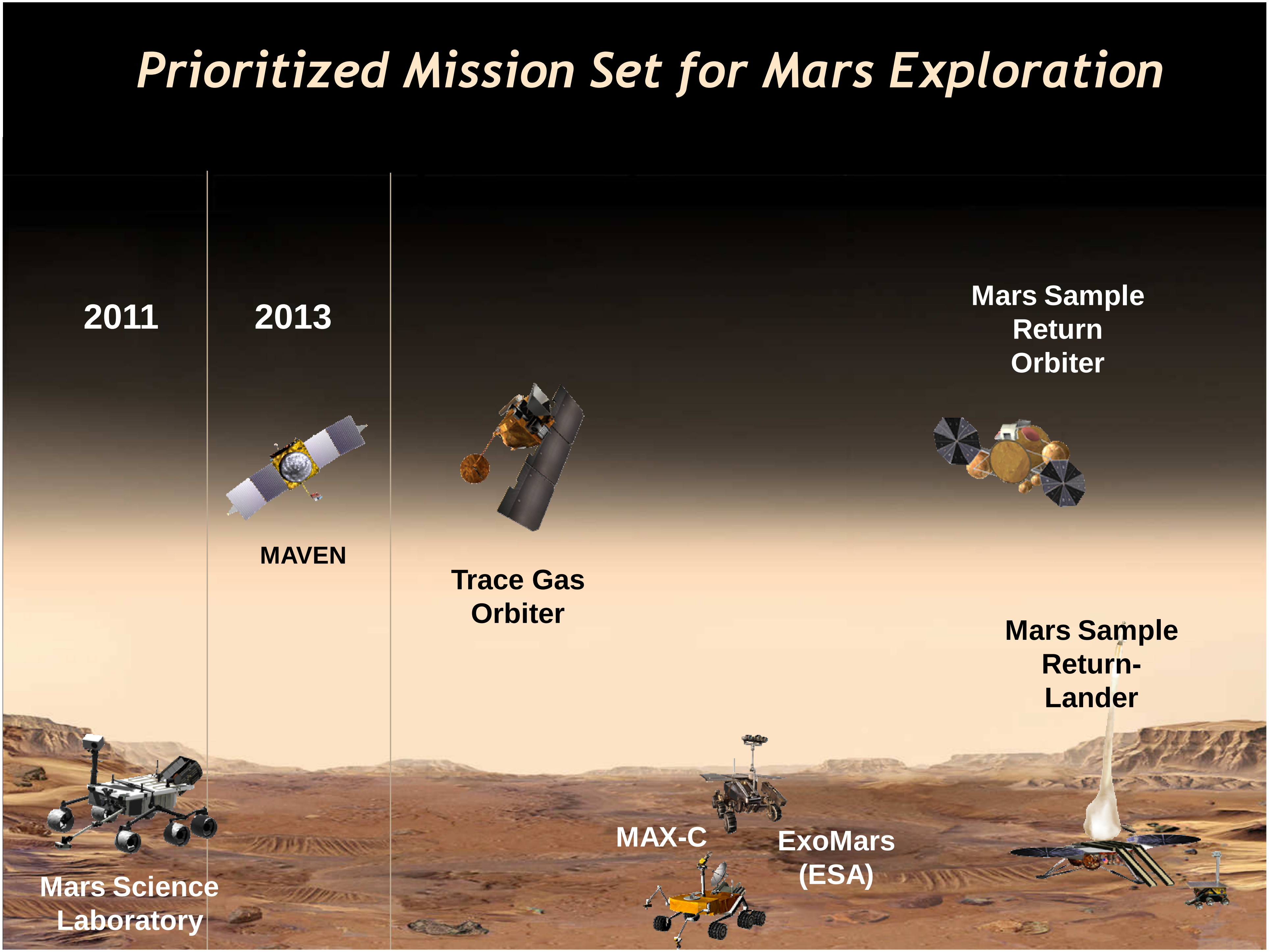
- Sample diversity
  - Multiple sample suites that represent the diversity of the products of various planetary processes
- Acceptable sample size/mass
  - The optimal sample size for rock samples is ~10 grams
  - ~30 gm regolith samples
- Number of samples
  - Rock samples: ~ 20
  - Regolith samples: several
  - Dust sample (if collectable): 1
  - Gas sample: 1
- No requirement to study samples on Mars
- Sample preservation needs
  - Retain pristine nature of samples (avoid excess heating, organic and inorganic contamination.)
  - Samples packaged to ensure that they do not become contaminated or mixed



This rock is chemically very different from others encountered by Spirit, implying formation by a different process.

Test sample that experienced 3400 g in a tube that remained sealed—such a sample would meet ND-SAG requirements

SOURCE: ND-SAG (2008), iMARS (2008)


Prioritized Mission Set for Mars Exploration
2011
2013
Mars Sample
Return
Orbiter
MAVEN
Trace Gas
Orbiter
Mars Sample
Return-
Lander
MAX-C
ExoMars
(ESA)
Mars Science
Laboratory